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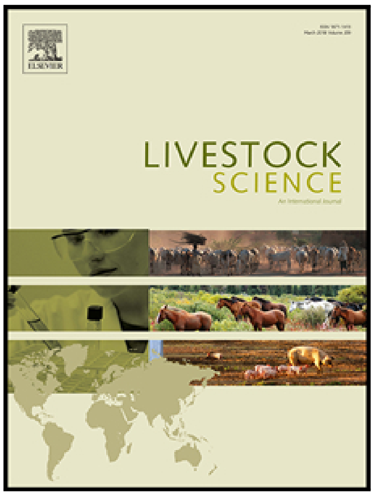

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Highlights

- Spruce was consumed more quickly than other wood types.
- Pigs interacted with spruce more frequently than other wood types.
- No time effect was found on wood use.
- Replacement rate rather than cost may be a practical concern.

Use of different wood types as environmental enrichment to manage tail biting in docked pigs in a commercial fully-slatted system

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Abstract

Provision of adequate environmental enrichment on pig farms is a legal requirement under current EU legislation and also alleviates the risk of tail biting. Wood is an organic alternative where loose bedding, which has been identified as the optimal enrichment, is not possible on fully-slatted floors since it may disrupt the slurry system.

The study compared four different wood types (beech (*Fagus sylvatica*), larch (*Larix decidua*), spruce (*Picea sitchensis*), and Scots pine (*Pinus sylvestris L.*)) as enrichment, taking into account the qualities of the wood, economic considerations, and effectiveness at reducing damaging behaviours and lesions. A total of 800 tail docked finisher pigs on an Irish commercial farm were used. Eight pens were provided with each wood type (25 pigs/pen), and the study was conducted over 2 replicates in time. In each pen a single wooden post was presented to the pigs in a metal dispenser with two lateral chains during the finisher period (12 to 22 weeks of age). The rate of wear, moisture content, and hardness of the wood along with lesion scorings and behavioural observation on pigs were monitored. Spruce was consumed more quickly than other wood types in terms of weight loss and reduction in length ($P<0.001$), resulting in a greater cost per pig. Pigs were observed interacting with the spruce more frequently than the other wood types ($P<0.05$). Pigs also interacted with the wood more often than the chains in spruce allocated pens ($P<0.001$). Overall the interaction with wood posts did not decline significantly across time. However, there was no difference in the frequency of harmful behaviours (tail/ear/flank-biting) observed between wood types, and also no difference in the effectiveness of the different types of wood in reducing tail or ear damage. There was a positive correlation between ear lesion and tear-staining scores ($r_p=0.286$, $P<0.01$), and between tail lesion and tail posture scores ($r_p=0.206$, $P<0.05$). Wood types did not affect visceral condemnation obtained in the slaughterhouse. Wood is a potentially suitable enrichment material, yet the wood species could influence its attractiveness to pigs.

Keywords

Finishing pigs; harmful behaviours; wood posts.

1. Introduction

Tail biting is one of the most serious issues in pig farming. It negatively affects both pigs and farmers, causing injuries and distress to the former and economic loss to the latter (Harley et al., 2014). The causes of tail biting are multifactorial, and involve numerous risk factors. These range from internal factors such as genetics, gender, age, and health of the pig, to external factors, including ventilation, feeding, stocking density, and environmental enrichment (Schrøder-Petersen and Simonsen, 2001; Zonderland, 2010; D'Eath et al., 2014). This makes tail biting especially difficult to prevent and control. Despite an EU Council Directive stating that routine tail docking is banned as a preventive measure to control tail biting (Council Directive 2008/120/EC), tail docking is still commonly used for this purpose, with some countries having almost 100% of pigs docked (Harley et al., 2012; D'Eath et al., 2016). However, tail docking does not eliminate tail biting. In Ireland, even though 99% of pigs are tail docked, over 25% of pigs still have identifiable tail-lesions during carcass inspection (Harley et al., 2014).

Inadequate environmental enrichment has been identified as a major risk factor for tail biting (EFSA, 2007). Provision of loose straw is generally considered the gold standard in successfully reducing, even if not completely eliminating, tail biting (Schrøder-Petersen and Simonsen, 2001; Van de Weerd et al., 2006; Studnitz et al., 2007; Scollo et al., 2013), but it needs continuous replenishment which increases production costs and labour. Moreover, on fully-slatted floors loose straw can obstruct faeces from going through the slats, or block the drainage system (D'Eath et al., 2014). These issues create a "systemic inertia" against use of loose straw amongst farmers who use the slatted systems (D'Eath, 2015). Therefore, economically feasible materials appropriate for slatted systems and capable of satisfying pigs' behavioural needs (Studnitz et al., 2007; Van de Weerd and Day, 2009) need to be identified.

In March 2016, the European Commission issued a recommendation regarding management of tail biting in pigs, reiterating that enrichment materials should be edible, chewable, investigable, and manipulable (European Commission, 2016a). Wood was categorised as a suboptimal enrichment, yet appropriate for use in fully-slatted systems where loose bedding cannot be provided (European Commission, 2016b). A recent survey of farmer attitudes to enrichment and tail biting in Ireland found that wood was frequently used, or that they would consider using it in the future (Haigh and O'Driscoll, 2016). Effectiveness and longevity were the two strongest factors influencing their decision making, followed by cost. These two criteria may appear to be paradoxical as more effective enrichment materials are usually more destructible and less durable (Van de Weerd et al., 2003). Examination of these features is one of the areas of focus for the current study.

Canning et al. (2013) have compared two methods of wood provision in pigs, and found that as a rooting device, when the wood was positioned touching the ground, it was less frequently used than a hanging lever device, due to soiling of the wood. Both hard and soft woods were used in that study, but the specific wood species were not reported. Telkänranta et al. (2014) compared wood (a hanging fresh branch of birch *Betula pendula* and *Betula pubescens*) with chains, and polythene pipe. When all enrichment types were present, pigs tended to interact with branches more. Moreover, although time spent performing harmful behaviours did not decrease, where wood was present pigs sustained less ear and tail damage. However, pigs in this study were housed on partly-slatted floors and all pens were also equipped with a straw rack, a metal chain and wood shavings. Thus the results may have been different if only wood was used.

Research comparing different wood types as enrichment has been mostly conducted on small animals. Ditewig et al. (2014) reported that enrichment type did not influence rat physiology when provided with an aspen (*Populus*) wood block. However, softwoods can contain aromatic hydrocarbons that may be toxic after long term consumption, and can damage liver function of rodents and rabbits (Froberg-Fejko, 2012). It is not known if there could be a similar effect on visceral deterioration in pigs after using wood, although no other detrimental effect of wood type enrichment on the carcass has been reported in meat rabbits (Jordan and Štuhec, 2002; Kermauner et al, 2004; Jordan et al., 2008). Moreover, to date no research has been undertaken to directly compare different wood types on the effectiveness of reducing tail biting in pigs in a fully-slatted floor system for pigs.

The objective of this study was to investigate whether different wood types would vary in their durability and effectiveness as environmental enrichment materials in terms of reducing pigs' harmful behaviours and lesions, and also to determine whether the provision of wood had any detrimental effects on pig health and performance that would potentially prevent the uptake of this enrichment by farmers. We hypothesised that different wood types would have different durability and effectiveness in reducing harmful behaviours and severity of lesions, and that wood would be a suitable enrichment material to use without any negative impact on pig health and performance.

2. Materials and methods

2.1 Animals, study design and housing

The experiment was conducted on an Irish commercial farm with a herd size of 2000 crossbred (Large White x Landrace) sows in Co. Cork, Ireland, and the disruption of the usual farm practices were minimised while carrying out the experiment. A total of 800 short-docked pigs (with an approximate length of 5cm when entering the finisher house), housed in 32 mixed-sex groups of 25 pigs, were followed in this study from entering the finisher stage (about 12 weeks of age; 42.71±1.17 kg) for 9-10 weeks until slaughter (21-22 weeks of age). The experiment was replicated over time, with 400 pigs included in each replicate. The sexes of pigs were randomly mixed in each pen, and the males were not castrated. In the weaner stage the pigs were given rubber hanging toys and in the grower stage one round Scots pine (*Pinus sylvestris L.*) wooden post. Traditional Trowbridge-style finishing pens were used in the experiment. These were stable-like pens with one side open to the outside through automatically thermal-controlled flip-up covers, all in the same row facing the same direction. The pens measured 6.2 m × 2.4 m, with a common feeding trough across the pen on one side of the wall (25 cm feeder space per pig), and a fully-slatted concrete floor. The feed provided was home-milled, standard commercial finisher diet, delivered four times per day. The pigs had access to a water drinker, natural ventilation and natural light.

At the time of movement to the finisher house, pigs were weighed and divided into groups of 25 (i.e. 16 groups of 25 pigs per replicate). Each group was then assigned by weight to one of four blocks. Within each block, one group was randomly assigned to each of the following 4 wood types from the start of the finisher stage until slaughter: one squared beech (*Fagus sylvatica*) wooden post (average starting length 1.217m, weight 2.205kg, circumference 0.200m), one squared larch (*Larix decidua*) wooden post (average starting length 1.219m, weight 2.48kg, circumference 0.228m), one squared spruce (*Picea sitchensis*) wooden post (average starting length 1.098m, weight 1.06kg, circumference 0.194m), and one round Scots pine (*Pinus sylvestris L.*) wooden post (average starting length 1.129m, weight 2.07kg, circumference 0.233m). Bark was removed from all the posts. The Scots pine was already in use on the farm and was supplied by the dispenser manufacturer (Jetwash Ltd., Ireland); the other three types of wood were bought in from sawmills, were untreated, and were of similar size within each wood type. Wood species were chosen for their different hardness and moisture levels based on a pilot study. Each wood type was used in 4 pens per replicate and thus 8 pens in total. As under current EU legislation (Council Directive 2008/120/EC) provision of environmental enrichment is mandatory, for ethical and legal reasons no negative control (no enrichment) treatment was applied.

For all wood types, the wooden posts were provided to the pigs using a commercially-available metal dispenser (Jetwash Ltd., Ireland). The dispensers consisted of a vertical metal cylinder (H 0.30 m × 0.08 m in diameter) which was attached to the wall opposite to the feeder trough, into which wooden posts were inserted (Figure 1). The wood drops through the metal cylinder, and is supported by a metal plate 0.2m below the bottom end of the cylinder, leaving the wood post exposed for access by the pigs between the bottom of the metal cylinder, and the supporting plate underneath it. Chains were attached to either side of the bottom of the cylinder, hanging next to the exposed wood to attract pigs' attention. The dispensers were installed so that the lowest part (the metal plate) was 0.2m above the surface of the pen floor.

The Scots Pine was provided to the farm for free by the dispenser manufacturer, but the unit price for subsequent purchasing was obtained. The other 3 types of wood posts selected were purchased based on price per wood post. Due to variation in the starting weight between posts, the cost was calculated using the average starting weight and calculating price per kg. The cost for

Scots pine, beech, larch, and spruce was 170, 167.35, 157.42, and 171.31 Euro cents per kg respectively.

2.2 Wood measurements

Prior to the start of the experiment and subsequently each week the following measures were taken on the wooden posts: weight (kg), length (m), circumference (m, taken at 0, 0.1, and 0.2m from the bottom of the post where it was exposed for pigs' use), hardness (shore D scale, measured using a durometer AD-300, Checkline Europe, and three randomly determined readings taken at 0, 0.1, 0.2, and 0.4m from the bottom of the post), and moisture level (%, using Hydromette BL-H-40, Gann, Germany, taken at 0, 0.1, 0.2, and 0.4m from the bottom of the post). The moisture meter employed two probes manually hammered into the wood post. Thus only one reading was taken to maintain the integrity of the post and reduce the risk of weakness or damage from excessive hammering. The moisture reading was automatically adjusted by the device to take account of the local temperature. In a situation where knots in the wood were exposed and needed to be removed manually these were weighed, and the date recorded. The wooden posts were replaced whenever the cylinder was emptied so that there was always wood available to the pigs.

2.3 Animal-based measures

Direct behaviour observations were carried out by 2 observers on a fortnightly basis starting from a week after the trial began. Inter-observer reliability was tested using Pearson's correlation (r_p=0.849, $P<0.001$). Two sessions of observations of each pen were carried out (at 11am and 3pm to avoid clashing with feeding), and each session last for 3 minutes (total of 6 minutes/pen/day). The ethogram was adapted from van Staaveren et al., 2015 (Table 1), and focused on harmful, social and play behaviours, as well as interaction with the enrichment device. Interaction with the enrichment device was recorded as either interaction with the wooden post or the metal dispenser (i.e. the cylinder and the chains). Before the observations began, the flaps at the entrance to the pens were opened, and the observer walked along the external corridor, habituating the pigs to human presence and waiting for the pigs to resume normal activities (no longer than five minutes). The observer then stood immediately outside the door to each pen to perform the observation. Due to the layout of the Trowbridge housing, the observer needed to keep a close proximity to the pen to be able to observe the whole pen. The observation only started once the pigs had ceased startling reactions and resumed normal behaviours to keep the observer effect to a minimum. The frequency of behaviours was manually recorded.

Tail and ear lesions, and tear staining were scored individually at the time of assignment to treatment, and on a fortnightly basis thereafter. Recordings were taken from pigs inside the home pen. Due to safety concerns, the last lesion scoring was in week 6 (when pigs were 18 weeks of age). Tail lesions were scored using the system adapted from Hunter et al. (1999; Table 2). In addition, the posture of each tail was recorded at the moment of tail lesion scoring (0: upward, 1: between up and down including sticking straight out, 2: Down pointing towards body; from Zonderland et al., 2009). Scoring for ear lesions was based on the system published by Telkänranta et al. (2014) and a pictorial guide (Table 3) developed by Diana et al. (in prep). Tear staining scoring was carried out using the DeBoer-Marchant-Forde Scale (Score 0-5; DeBoer et al., 2015). Again, due to constraints of scoring pigs in the home pen with regard to the recorder's safety and the subject's head orientation and visibility, only one eye (whichever was easier to view) was scored for each pig following the DeBoer et al. (2015) scoring system.

2.4 Production performance and carcass data

Pigs were weighed as a group at the start of the trial, and they were tattooed for group identification before being sent to the slaughterhouse. The cold carcass weight of each pig was recorded at the slaughterhouse. The tail damage on each carcass was inspected by a single observer on the processing line using the carcass tail lesion scoring system of Harley et al. (2012). Carcass and visceral condemnations, especially digestive and liver damage that might relate to wood use, were recorded on the slaughter line following the instructions from the veterinary inspectors on site.

2.5 Statistical analysis

Statistical Analyses System (SAS, version 9.1.3, 1989, SAS Institute Inc., Cary, NC) was utilised to analyse the data. Data were initially screened for outliers by using the univariate procedure. Residuals were checked for normal distribution, and only the loss of length needed to be transformed using log10 before analyses. Tukey-Kramer adjustments were used to examine differences between least square means.

Wood data were analysed using Linear Mixed Models (LMMs), including the fixed effects of treatment, time (week 0 to 10) and replicate, and the random effect of pen. The position where readings of circumference, moisture and hardness of the wood post were taken was also considered as a fixed effect. The cost comparison was based on weight loss (kg/week) multiplied by the unit price of each type of wood, and the average of 10 week in the finisher stage was used to estimate the cost per pig.

Behavioural data were analysed as frequencies per minute. Interaction with the enrichment was further broken down into percentage of interaction with the wooden post or the metal dispenser, and differences in the frequency of interaction between the two were also analysed. LMMs were used to analyse the data, using the fixed effects of treatment, time (week 1, 3, 5, 7, 8) and replicate, and the random effect of pen was also included. The interaction between treatment and time was also considered.

All lesion scores were recorded individually for each pig but analysed as both a percentage in group and a group mean as no individual identification was available. LMMs were used, including the fixed effects of treatment, time (week 0, 2, 4, 6) and replicate, and the random effect of pen. Pearson's correlation was used to investigate associations between different lesion scores, and these were analysed at the pen level. Production performance were analysed by initial weight and cold carcass weight, also using LMM, including the fixed effects of treatment and replicate, and the random effect of pen.

3. Results

3.1 Wood measures

There was a difference between types of wood in the rate of decrease in weight ($F_{(3, 22.6)}$=8.79, P<0.001) and length ($F_{(3, 27.9)}$=17.8, P<0.001). Spruce showed the greatest reduction in both weight and length compared to the other three species, which were not significantly different from each other; however, beech was numerically the most durable (Figures 2 and 3). Hardness also differed significantly between wood types ($F_{(3,36.8)}$=34.03, P<0.001). Post-hoc testing showed that beech was harder than all other types of wood (P<0.05), larch was harder than spruce and Scots pine (P<0.001), while spruce and Scots pine did not differ from each other (Figure 4). Finally, Scots pine had a higher moisture level than spruce and larch ($F_{(3,28)}$=8.47, P<0.001; Figure 5).

In terms of circumference, there was an effect of both wood type and position on the wood post. Similar to weight and length, the change in circumference was greater in spruce (0.071±0.009m) than in larch (0.013±0.013m) and beech (0.006±0.014m) ($F_{(3, 33)}$=7.67, P<0.001). At the highest measuring point (0.2m from the bottom of the wood post) the change was the smallest (0.022±0.006m; $F_{(2,908)}$=15.77, P<0.001) compared to at 0m (0.030±0.006m) and 0.1m (0.034±0.006m). There was no effect of time (weeks of the experiment) on the rate of weight loss, length reduction or change in circumference.

Cost difference was calculated based on kg of wood loss per week. Across the wood types, the difference in cost (€) per week was significant; spruce was higher (€0.46/week) than Scots pine (€0.12/week), beech (€0.10/week) and larch (€0.14/week) ($F_{(3,19.2)}$=9.19, P<0.001). When the cost per pig during the entire finisher stage (10 weeks) was compared, spruce, Scots pine, larch, and beech cost €0.18/pig, €0.04/pig, €0.04/pig and €0.02/pig respectively. On the farm where the experiment took place, the enrichment was reused between batches, but if the value of the remaining posts was taken into account (i.e. the posts were discarded after each batch), there was no difference in terms of cost between wood types during the experiment.

3.2 Behavioural assessment

There was no difference between wood types in the frequency of interaction with the entire device (wood post and the metal dispenser; Table 4). However, when considering only the wood, more interaction occurred with spruce than beech ($F_{(3, 81.2)}$=3.46, P<0.05; Figure 6). Moreover, the proportion of interaction with wood relative to those with the entire enrichment device was also higher in the spruce pens (45.63%) than in beech pens (28.34%) ($F_{(3, 85.7)}$=4.03, P<0.01). By contrast, there were more interactions with the metal dispenser than the wood post when given beech (P<0.001) and larch (P<0.01), while in Scots pine and spruce pens no difference was found.

There was no difference in the frequency of tail biting, ear biting or other harmful behaviours between wood types, nor was there a difference when all damaging behaviours were combined (Table 4).

There was an effect of time on some of the behaviours observed (Table 5). Overall activity level (i.e. the sum of all frequencies of all behaviours) was the lowest in week 8 ($P<0.001$). The highest frequency of tail biting was observed in week 5 ($P<0.001$), and ear biting in week 7 ($P<0.001$); similarly, in week 7 there was a peak in the frequency of all harmful behaviours combined (tail + ear + flank biting + belly nosing, $P<0.001$). The interaction with the entire enrichment device was significantly lower in week 8 ($P<0.001$) than week 1, 3, and 5, and the interaction with chains and metal dispenser was the lowest in week 8 ($P<0.001$; Table 5), but there was no difference in the interaction with the wood post across time considering all wood types (Figure 7).

3.3 Lesions and tear staining scorings

There was no effect of treatment on lesion scores, but the mean tail lesion scores were lower than 1 which represented mild scratches, and ear lesions recorded were mostly superficial scratches during the experiment (Table 6).

There was an effect of time on both lesion and tear staining scores. Tail lesion scores were the lowest in week 1 ($P<0.001$), and tear staining score also increased across time with the lowest score in week 0 and highest in week 6 ($P<0.001$; Table 6). The highest ear lesion scores occurred in week 0 and week 6 of the study ($P<0.05$).

A positive but weak correlation was found between pen-based ear lesion and tear-staining scores ($r_p=0.286$, $P<0.01$), and tail lesion and tear-staining scores (r_p=0.076, P<0.001). Similarly there was a positive but weak correlation between tail lesion and tail posture scores (r_p=0.206, P<0.05).

3.4 Production performance and carcass data

The average pig weight at 12 weeks of age (at the start of the experiment) was the same across wood types (Scots pine 43.4±1.14kg, spruce 42.45±1.14kg, larch 42.65±1.14kg, beech 42.35±1.14kg). There was no significant difference in the recorded cold carcass weight between wood types, and no visceral condemnation was found at slaughter that could be attributed to wood consumption. Tail lesions scored on the carcass corresponded with the tail lesions scored alive, where pigs in rep 2 (0.99±0.05) had worse tail lesions than rep 1 (0.72±0.05; $F_{(1, 26.1)}$=13.94, P<0.001).

4. Discussion

The aim of this study was to investigate whether different types of wood used as environmental enrichment would perform differently in terms of durability, attraction to the pigs, and effectiveness in control of tail biting. To this aim, we selected wood types with varying degrees of hardness and moisture levels to better understand how these traits would affect their performance as an enrichment material. Spruce, which was softer, was used up more quickly than the other three, likely because it was more easily degradable by oral manipulation. Moreover, the overall frequency of interactions as well as the proportion of interactions with the wood post compared with the metal device was the highest in the spruce pens. This suggests that pigs preferred the softer wood posts to the metal dispenser while at the device. Indeed studies on different enrichment materials have shown that being destructible contributes to higher interaction from the pigs (Van de Weerd et al., 2003; Studnitz et al., 2007; Van de Weerd and Day, 2009).

Scots pine and beech had the highest moisture levels, suggesting that although spruce was the softest and most easily degradable, this was likely not to be related to its moisture content. Beattie et al. (1998) compared different types of substrates and used preference testing to understand which material pigs preferred. They concluded the texture had a greater influence on pigs' preference than moisture. This ties in with our results as there was no obvious relationship between moisture level and the frequency of use or rate of wear. A lower moisture content of spruce could provide a benefit in terms of preservation and long term storage. The high moisture content of the Scots pine may explain the smaller margin in weight loss even though it had the same level of hardness as spruce. It could also be due to the presence of knots, which were only observed in this wood type.

The weight loss, length reduction or change in the circumference of the wood posts was not different between weeks. This constant wear suggests that all wood types sustained ongoing interest from the pigs, which was also supported by the behavioural data. In contrast, the frequency of interaction with the metal dispenser and chains was significantly lower at later stages of the experiment. Previous studies have shown that the qualities of enrichment being edible and destructible contributed to a sustained interest from pigs (Van de Weerd et al., 2003). Although compared to loose bedding such as straw, the quantity used and replenish rate of the wooden posts was lower (D'Eath et al., 2016), they possess these qualities whereas the metal part of the device does not. This could explain why the posts attracted the pigs' attention for the duration of the experiment. Nevertheless, the study demonstrated that different wood types have different levels of these qualities, a consideration which is important to take into account when supplying enrichment.

Trickett et al. (2009) used loose wood blocks placed on the floor and found no effect of time on the interaction, but it was always lower with the wood block than with rope, or treatments combining and alternating rope and wood blocks. This may be due to the non-deformability of the wood block chosen. These authors also reported the importance of presentation of the enrichment; keeping the enrichment clean and in sight increased the pigs' frequency of interaction. In the current study, by using the dispenser, the wood was kept from the ground, reducing the possibility of soiling. Moreover, being edible and destructible also means that the wood was somewhat renewable. Fresh wood dropped down through the dispenser as the lower part of the wood was consumed, which acted as a self-replenishing mechanism and provided a novel surface for interaction. As the wood dropped down, the shape of the wood post also changed, as demonstrated by the variation in circumference. The combined effects of these features provide possible explanations as to why the wood posts sustained the pigs' attention for a longer period. In the spruce pens, when a post was used up, a new one was replenished, which also enhanced the novelty effect. The Scots pine was routinely used on the farm in the grower stage as enrichment, which might explain why it showed a trend of reduced interaction over time compared to the other 3 types of wood, which were only introduced to the pigs in the experiment from 12 weeks onwards. Thus, the different wood types might have been regarded "sufficiently different" by the pigs, resulting in the different patterns of interaction frequency.

The price for all wood types used was similar at the time of the study (January to June 2016), but due to the different rate of weight reduction, using spruce cost 9 times more than beech and 4.5 times more than Scots pine and larch. D'Eath et al. (2016) carried out a cost comparison of different scenarios of housing and enrichment provision with their respective capacity to manage tail biting. That study reported that in a partly slatted standard housing with docked pigs ("standard docked scenario"), the enrichment cost was estimated based on €0.17 per pig during the finisher stage, which was similar to the cost of spruce in the current experiment. Based on these results, and the fact that the "standard docked scenario" had a lower tail biting outbreak probability than non-docking, using spruce to manage tail biting could be economically feasible in a slatted system with docked pigs (D'Eath et al., 2016). Nevertheless, docking is not permitted routinely in the EU, and thus our results with regard to cost are only applicable in a docked situation, as when pigs are not docked an increased enrichment allowance is necessary (Chou et al., 2018). A significant factor which could hamper the farmer's willingness to adopt this management approach would be a necessity to continual replenishment of the wood posts and the extra labour time that could incur.

During the course of the experiment, there were no serious tail and ear biting incidents, and the lesions observed were mostly mild superficial scratches. This might in part explain why there was no difference between wood types with regard to the pig-based measures. The overall recorded activity was the lowest in week 8, which could be a result of pigs' heavier weight, and consequently less space available in the pen, in agreement with previous studies (Van de Weerd et al., 2005; Scollo et al., 2013). The highest level of tail biting in the study occurred in week 5, which also corresponds to previous research (Van de Weerd et al., 2005; Schrøder-Petersen and Simonsen, 2001), However Scollo et al. (2013) found that when finisher pigs were reared to reach a heavier weight, tail biting increased at week 14. It is widely acknowledged that the triggers leading to the onset of tail biting are multifactorial (D'Eath et al., 2014), with stocking density (as well as other factors such as tail length, ventilation, genetics etc.) playing a role in increasing biting behaviours.

The highest frequency of ear biting was observed in week 7. Very little is known about the development of ear biting in pigs in the published literature. In terms of lesion scores, the lowest tail lesion score was recorded at the beginning of the experiment which supported the behavioural data, as this was when the lowest level of tail biting was observed. Entering a new environment (i.e. the finisher pens) with a greater space allowance per pig could have diverted the pigs' attention away from tail biting. Conversely, ear lesions were more severe at the beginning and week 6 of the experiment. The former might be caused by the stress of mixing upon entering the finishing stage and the latter might be from more frequent ear biting behaviour observed during that period. As the final lesion scores were obtained in week 6, any interpretation of the relevance of such findings at this time is limited.

Tear staining has been shown in laboratory rats to be an indicator of social stress (Mason et al., 2004). In pigs, there is the suggestion that the occurrence of tear stains could be a symptom of nasal inflammation (such as atrophic rhinitis) or exposure to ammonia (Done et al, 2012; Register et al, 2012). However, DeBoer et al. (2015) found that laboratory pigs housed in visually isolated pens had significantly higher tear staining scores than pigs with social visual stimulation, suggesting a link to stress, in this case associated with isolation. Although in the current study only one eye from each pig was scored on each recording occasion, DeBoer et al. (2015) scored both, and found the results consistent between eyes. In the current study, all pigs were group housed in similar conditions with no known issue of nasal disease on the farm, and thus any potential differences in tear staining between treatments could have been due to the wood type.

Similar to what DeBoer et al (2015) found, there was no effect of enrichment treatments on tear staining, but the positive but weak correlation between tear staining and ear and tail lesion scores could suggest the pigs were under higher level of stress resulting from more biting. Telkänranta et al. (2016) also reported a positive correlation between tear staining and the occurrence of tail and ear lesions, albeit similarly with a low coefficient. These authors also noted the great variation of scores within pen. They suggested that tear staining has potential as an indicator to identify individual pigs with particularly high stress levels within a pen, although further work is needed to determine the cause of the high level of variation. The variation between individual pigs may itself be a resultant from the level of tear staining a pig can generate, rather than the stress it experiences. Feedback from the farm staff revealed a high interest in tear staining scoring as it is relatively easy to notice during routine inspection. This measure might thus have the potential to be utilised as a practical on-farm inspection tool if further validation of its effectiveness in detecting higher level of stressful conditions, such as excessive tail and ear biting, could be obtained.

Some research has suggested tail posture could be used as a prediction of tail biting outbreaks (Zonderland et al, 2009; Paoli et al, 2016). In the current study the positive correlation between tail lesion and tail posture was significant but also with a low strength. This could be due to the fact that no major tail biting outbreak occurred, and neither were serious tail lesions observed during the experiment. Moreover, as the Trowbridge housing prevented the tail posture being scored outside the pen, the results could have been affected by the pig's reaction to human approach since the tail posture was also shown to indicate the emotional state of pigs (e.g. fear and excitement) (Kiley-Worthington, 1976; Reimert et al., 2013). Nevertheless, as pointed out by Paoli et al. (2016), even in docked pigs, pointing the tails downwards towards the body could work as a defensive measure if the pigs were prone to being victims of biting.

In the current study, and even in the absence of severe tail biting occurrences, the tail posture in docked pigs could still be a relevant measure to detect ongoing prevalent tail lesions in the pens.

Conclusion

The performance of different wood types varied with regard to durability and attraction to pigs: softer wood was less durable but it attracted pigs' attention more. Thus when using wood as environmental enrichment for pigs, the wood type chosen should be taken into consideration, as softer types of wood are likely to sustain more frequent and longer attention from pigs. Other traits of wood, such as odour, shape, and taste, should be further explored with regard to attraction to pigs. Nevertheless, there was no difference in wood types with regard to effectiveness in reducing harmful behaviours or lesions, and the overall level of tail biting observed was low. No effect was found on production measures. Wood can be a potentially suitable enrichment material to manage tail biting in docked pigs when appropriate wood type is in use, but further work is still needed to verify its performance in conditions with a higher risk of tail biting.

Conflict of interest statement

The authors declare no conflict of interest.

Acknowledgements

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Figure captions

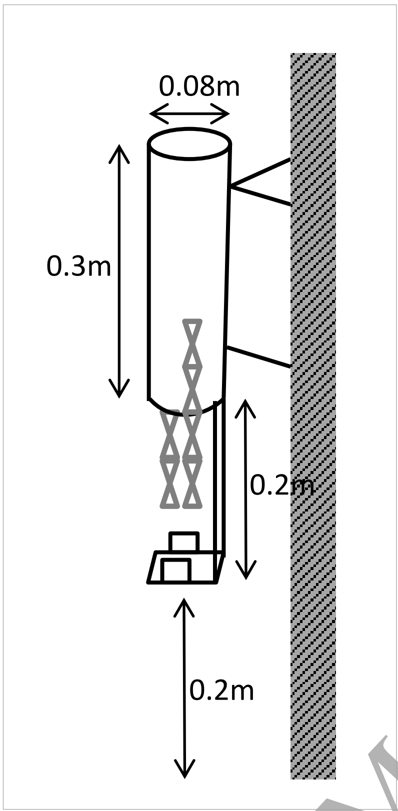

Figure 1. Schematic diagram of the wood dispenser.

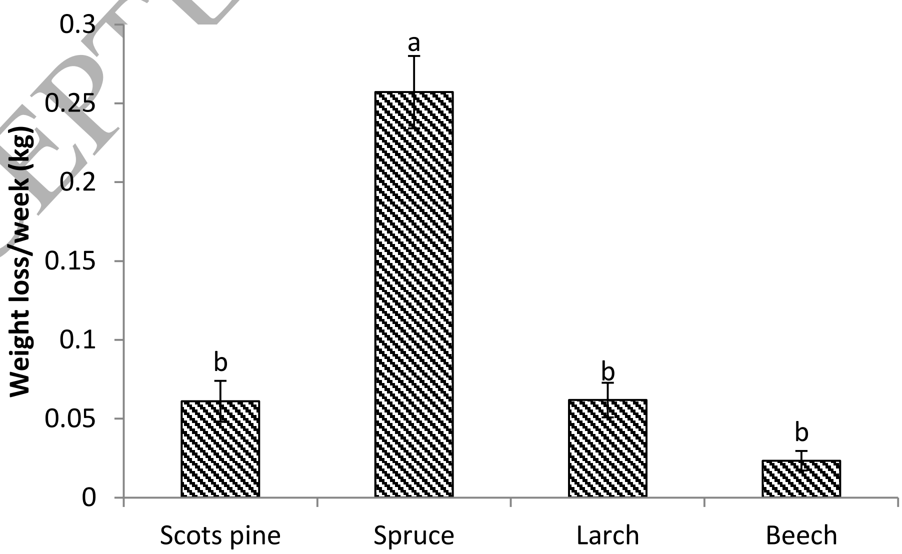

Figure 2. Weight loss of wood posts per week between wood types (LSmean±SEM). $F_{(3, 22.6)}$=8.79, P<0.001. Different letters denote significant differences determined using Tukey-Kramer test.

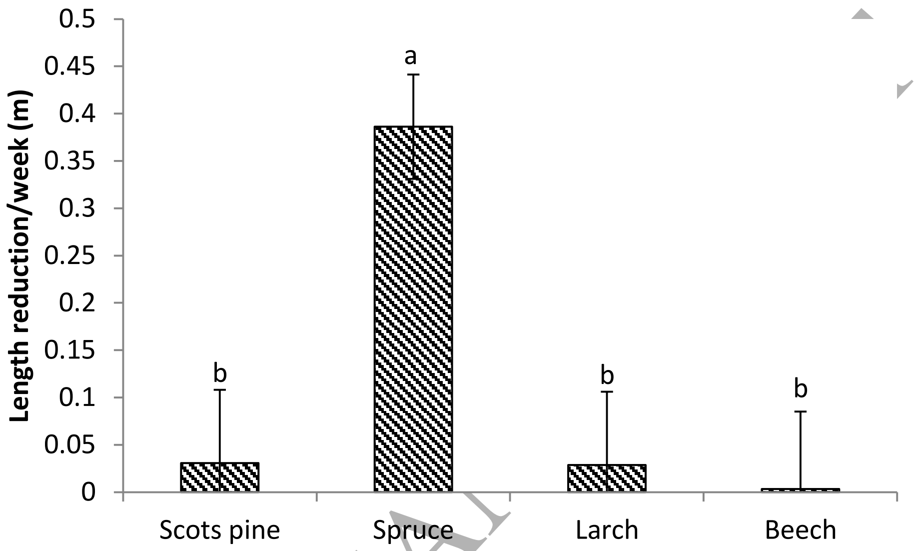

Figure 3. Length reduction of wood posts per week between wood types (LSmean±SEM). $F_{(3, 27.9)}$=17.8, P<0.001. Different letters denote significant differences determined using Tukey-Kramer test.

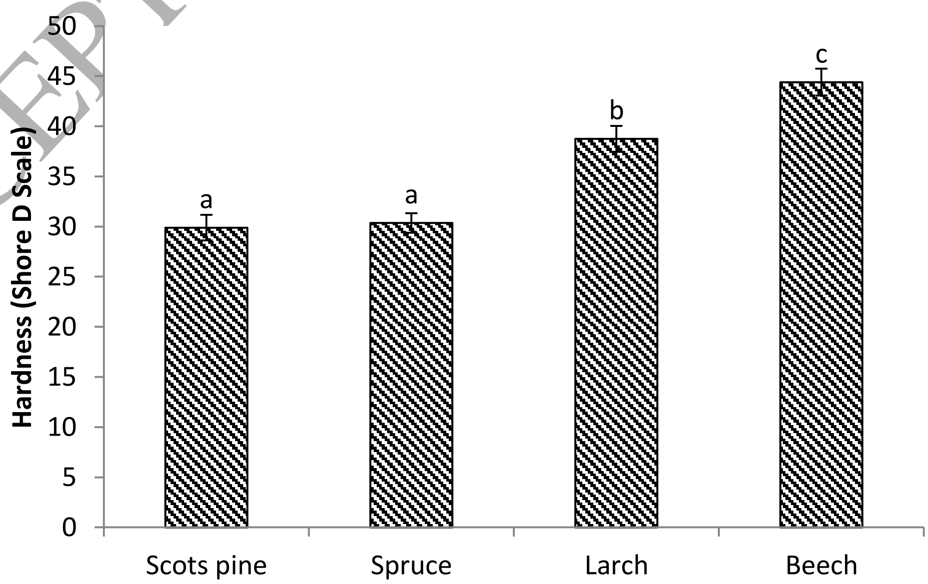

Figure 4. Hardness of wood posts between wood types (LSmean±SEM). $F_{(3,36.8)}$=34.03, P<0.001. Different letters denote significant differences determined using Tukey-Kramer test.

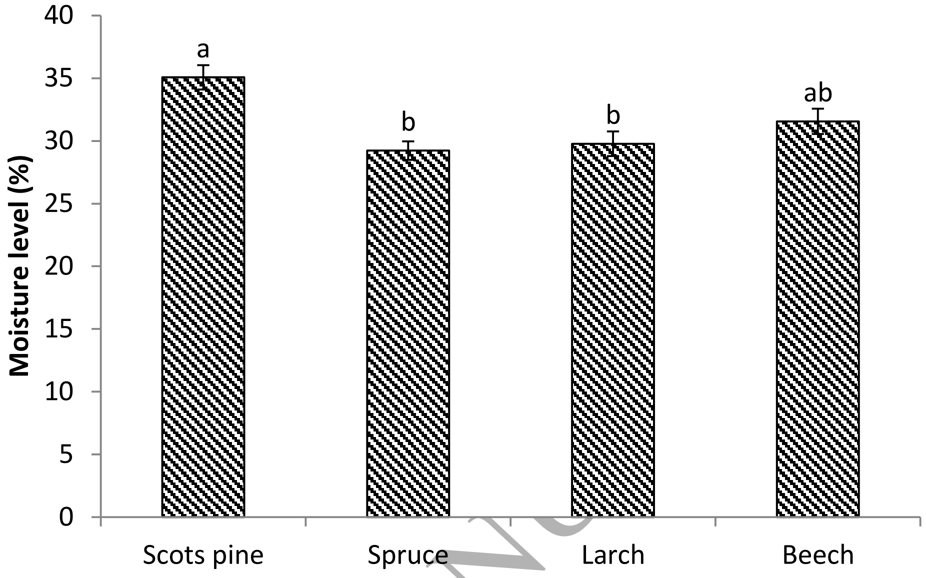

Figure 5. Moisture level of wood posts between wood types (LSmean±SEM). $F_{(3,28)}$=8.47, P<0.001. Different letters denote significant differences determined using Tukey-Kramer test.

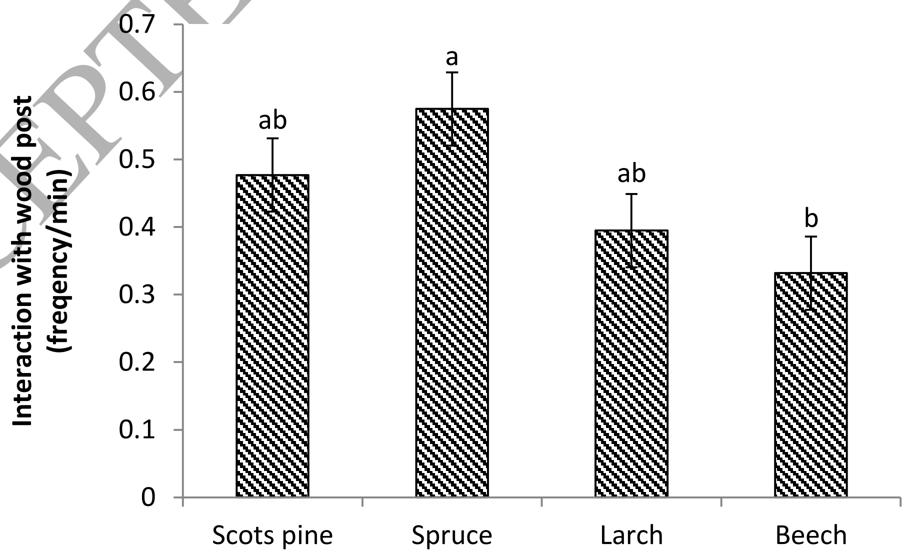

Figure 6. Frequency of interaction with wood posts between wood types (LSmean±SEM). $F_{(3, 81.2)}$=3.46, P<0.05. Different letters denote significant differences determined using Tukey-Kramer test.

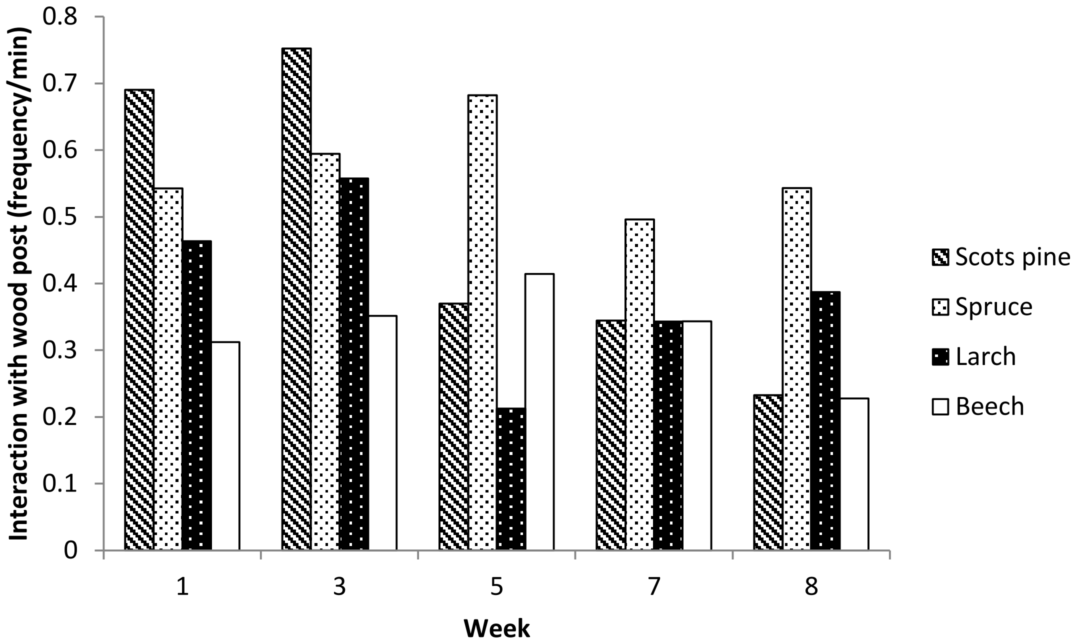

Figure 7. Frequency of interaction with the wood post per pen across time between wood types (LSmean±SEM). There was no significant difference between weeks or interaction between week and treatment.

Tables

Table 1. Ethogram for direct behaviour observation. All behaviours were recorded as frequencies.

Behaviours	Description
Tail biting	Tail in the mouth of another pig: ranges from tail being gently manipulated to tail being chewed/bitten
Ear biting	Ear in the mouth of another pig: ranges from ear being gently manipulated to being chewed/bitten
Flank biting	Oral manipulation including bites directed towards the flank of another pig
Belly nosing	Rhythmic up-and-down movement of the snout of one pig rubbing the belly of another
Fighting	Mutual pushing parallel or perpendicular, ramming or pushing of the opponent with the head, with or without biting in rapid succession
Mounting	Placing hooves on the back of another pig with or without pelvic movement
Play	Play behaviour, scampering, jumping/running around
Using wood	Any form of oral/nasal manipulation on the wood part of the enrichment
Using dispenser	Any form of oral/nasal manipulation on the dispenser part of the enrichment, including chains on each side and the metal dispenser itself

Table 2. Tail lesion scoring system

Score	Description
0	No evidence of lesions
1	Healed or mild scratches/punctures
2	Scratches and punctures that are wider than a pinhead with some visible redness
3	Swelling, fresh blood, apparent redness, possible pus and necrotic tissue and possible signs of amputation

Table 3. Ear lesion scoring adopted from Telkänranta et al. (2014). Category 3 is shown in bold as it was added in for the current experiment additional to the original system.

Score	Description
0	Undamaged ears.
1	Superficial scratches.
2	Evidence of recent bleeding.
3	**Bloody and red (substantial cuts and bleeding)**
4	Part of an ear missing.

Table 4. Behaviour frequencies (/min) observed between different wood types (LSmean±SEM). Different letters denote significant differences picked up by Tukey-Kramer test.

Behaviour	Treatment					F value	P-value
	Scots pine	Spruce	Larch	Beech	SEM		
Using enrichment	1.0837	1.1739	1.0011	1.0354	0.08	0.82	NS
Using wood	0.4777 [ab]	0.5714[a]	0.3957 [ab]	0.3279[b]	0.06	3.46	<0.05
Using dispenser	0.6084	0.5917	0.6085	0.6956	0.05	0.85	NS
Tail biting	0.4344	0.3827	0.3647	0.3532	0.65	0.5	NS
Ear biting	0.2125	0.1542	0.2417	0.1833	0.03	1.49	NS
Flank biting	0.1674	0.2201	0.247	0.2378	0.03	1.46	NS
Belly nosing	0.1235	0.1363	0.1201	0.08033	0.03	0.49	NS
All harmful*	0.9377	0.8921	0.9708	0.8575	0.07	0.47	NS
Fighting	0.2041	0.1833	0.1415	0.1959	0.03	0.73	NS
Mounting	0.2881	0.2536	0.3093	0.1827	0.05	1.2	NS
Play	0.2418	0.2172	0.2871	0.2111	0.05	0.41	NS

* All harmful behaviour = Tail biting + ear biting +flank biting + belly nosing

Table 5. Behaviour frequencies (/min) observed in all pens across time (LSmean±SEM). Different letters denote significant differences picked up by Tukey-Kramer test.

Behaviour	Week						F value	P-value
	1	3	5	7	8	SEM		
Using enrichment	1.18^{a}	1.36^{ab}	1.15^{ab}	0.95^{bc}	0.72^{c}	0.07	11.52	P<0.001
Using wood	0.50	0.56	0.42	0.38	0.35	0.06	2.31	P=0.06
Using dispenser	0.67^{ab}	0.79^{a}	0.74^{a}	0.56^{b}	0.37^{c}	0.04	16.12	P<0.001
Overall	2.78^{a}	3.07^{a}	3.03^{a}	2.74^{a}	1.71^{b}	0.14	18.13	P<0.001
Tail biting	0.23^{a}	0.35^{a}	0.64^{b}	0.39^{a}	0.31^{a}	0.05	8.47	P<0.001
Ear biting	0.22^{a}	0.15^{a}	0.09^{a}	0.39^{b}	0.14^{a}	0.03	11.44	P<0.001
Flank biting	0.18^{ad}	0.33^{bc}	0.08^{d}	0.32^{ac}	0.18^{ad}	0.03	8.08	P<0.001
Belly nosing	0.21^{a}	0.06^{bc}	0.02^{c}	0.17^{ab}	0.12	0.04	4.67	P<0.01
All harmful*	0.85^{a}	0.90^{a}	0.82^{a}	1.26^{b}	0.75^{a}	0.08	6.53	P<0.001
Fighting	0.10^{ac}	0.23^{ab}	0.37^{b}	0.16^{ac}	0.04^{c}	0.04	12.2	P<0.001
Mounting	0.27	0.28	0.35	0.22	0.17	0.05	1.97	NS
Play	0.38^{a}	0.29^{ab}	0.34^{ab}	0.15^{bc}	0.05^{c}	0.06	6.07	P<0.001

* All harmful behaviour = Tail biting + ear biting +flank biting + belly nosing.

Table 6. Average lesion scores recorded across time (LSmean±SEM). Different letters denote significant differences picked up by Tukey-Kramer test.

Score	Week					F value	P-value
	0	2	4	6	SEM		
Tail lesion	0.68[a]	0.81[b]	0.90[b]	0.90[b]	0.04	11.78	P<0.001
Ear lesion	1.12[a]	0.96[b]	1.08[ab]	1.12[a]	0.06	3.2	P<0.05
Tear staining	1.79[a]	2.05[b]	2.21[b]	2.59[c]	0.06	34.99	P<0.001